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Cave Assessment, Monitoring, and Management Recommendations for Horsethief Cave, Bureau of Land Management, Worland District, Wyoming.

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EXECUTIVE SUMMARY

Values and significance of the cave

Horsethief Cave is an extremely significant cave system. It contains six features which are particularly important. These are:

1. The cave is long and has complex passages; there is a great potential for additional discoveries. The cave is presently the longest cave in the United States west of South Dakota. We believe that additional discoveries will ultimately make this cave one of the 10 longest in the United States, and one of the 20 longest in the world.
2. The cave is characterized by an impressive diversity of cave features.
3. The nature, extent, diversity, and beauty of cave mineralization is of major national significance. Horsethief Cave is one of the best decorated caves in the northern United States, and the speleothems found in the cave represent a highly unique assemblage of exquisite features. Horsethief Cave is without question one of the most beautiful caves in the United States.
4. The cave is in very near-natural condition.
5. The cave contains paleontological and potentially archeological values which add to the diversity of cave features.
6. The cave has major recreational and esthetical values.

It is our conclusion that Horsethief Cave is of both state and national significance. Horsethief Cave is one of the most outstanding caves in the United States.

Threats to cave resources

1. Horsethief Cave is threatened by potential mining activities. It is our understanding that apparently valid mining claims for uranium exist on some of the lands underlain by the Horsethief Cave system. Uranium deposits in the area are associated with cave fills, speleothems, and breccia along active hydrologic systems. As a result, uranium mining would destroy cave values. We have recommended the following actions;

A) In view of the national significance of the cave, we recommend that BLM seriously consider the possibility of acquiring mineral rights in the area overlying and near Horsethief Cave. We do not have the expertise to fully appreciate how difficult this might be, but we are convinced that the natural values of Horsethief Cave are so significant as to warrant the perpetual protection of this outstanding cave.

B) Alpha radiation monitoring results from Horsethief Cave may be of help in assessing the economic viability of uranium claims in the vicinity of the cave. We recommend that these records be preserved in the files on the mining claims, and that they be reviewed by BLM geologists to evaluate their usefulness as an assessment tool.

2. Features in Horsethief Cave may be threatened by existing or future land use activities. Surface land use actions affect caves primarily

through hydrologic impacts. Modification of plant communities, diversion of surface waters (even by features such as roads and man-induced gullies), and impoundments can all have significant impacts on underlying and adjacent cave systems. The cave appears to underlie or be near part of a landing strip, some well established jeep trails, two intermittent streams, and one man-made watering pond (which dams one of the intermittent streams). We have recommended the following actions:

A) Man-made surface features should be correlated with cave features.

B) The stock pond in the NW¼ of Section 20 should be replaced by one outside of the cave area. The pond disrupts the natural water flow in the intermittent stream, and encourages concentrated livestock use with attendant increases in sediment production and soil compaction. All of these impacts could seriously affect underlying or adjacent cave passages. The area in the vicinity of the pond should be returned to as near-natural condition as possible, and should be carefully revegetated.

C) The impacts of the landing strip on the cave should be evaluated. Improvements to, or reconstruction of, this landing strip should not be permitted as such activities could harm the cave and cave features.

D) All future proposed land use activities in the north half of Section 20 should be evaluated to determine their potential impacts on the Horsethief Cave system.

3. Horsethief Cave is threatened by present visitation and use. The most significant present damage is related to the uncontrolled trampling of cave floors and features. We have recommended the following actions:

A) A management program should be instituted to curtail trampling of the floor and cave features. The program should protect cave resources while permitting cave visitation and exploration. The management program would involve the establishment of travel routes in the cave, and would require explanation to visitors and visitor cooperation.

B) Based upon damage which has already occurred to the cave from visitor use, we recommend that the admission quotas established in the 1978 BLM cave management plan not be increased. We believe that these limits are reasonable and necessary for the protection of the cave.

C) We question whether heavy use of cave resources of national significance in conjunction with the training program of the National Outdoor Leadership School is appropriate, and whether it represents the highest and best use of basically non-renewable cave resources. We recommend that BLM consider this issue in detail, particularly in view of our assessment that the cave and its features are of major national significance.

D) Restriction of use to selected user groups is not necessary for the protection of the cave, cave features, scientific resources in the cave, nor for the protection of cave visitors. We recommend that no user group be permitted to gain exclusive or primary use of Horsethief Cave.

E) We recommend that BLM contact the Heritage Conservation and Recreation Service about the possibility of designating Horsethief Cave as a National Natural Landmark. It is our conclusion that the site qualifies for such designation.

F) A good collection of photographs depicting features and conditions in Horsethief Cave, plus explanatory narration, would help BLM land managers better understand the resources and management situations associated with this cave. We recommend that such photographs be taken and the narration prepared.

G) The photo points which have been periodically photographed provide an important index for assessing visitor impacts on the cave. We recommend that these be re-photographed and analyzed at two or three year intervals.

Health and safety

There are eight hazards which may be associated with visitation of Horsethief Cave. These are listed below in descending order of importance:

1. The hazard of becoming lost.

2. The hazard of falls which result in injury.

3. The hazard of rockfall and shifting rocks.

4. The difficulty of rescue.

5. The hazard of dust.

6. The hazard of being trapped in the cave by a malfunction of the lock on the gate.

7. The presence of natural alpha radiation.

8. The potential presence of histoplasmosis.

Recommendations relating to these identified hazards are listed below.

The hazard of becoming lost

1. BLM cave management strategies should view people becoming lost as the most significant safety hazard in Horsethief Cave.

2. BLM's present recommendation to visitors that they place removable ribbons on their way into the cave, and remove them on their way out, is a prudent approach and should be continued.

3. All visitors should be cautioned that, in this cave, becoming lost is a real hazard.

4. All visitors should be advised to carry at least two sources of acceptable light.

Hazards of falls which result in injury

1. There are no areas of the cave which are particularly hazardous; this should be recognized in the cave management strategy.

2. Visitors should be cautioned to be particularly careful of their footing and to be particularly careful on climbs, because rescue of an injured person would be extremely difficult.

3. Parties with inexperienced , youthful, or awkward persons should be strongly encouraged to carry at least 40 feet of belay rope for the descent of the Gypsum Wall. Other groups need not take such equipment.

Hazards of rockfall and shifting rocks

1. Visitors should be cautioned that caves often have unstable ceilings, walls, and floors, and that visitors should carefully watch for such areas. This cautioning is prudent for all caves; care should be taken to not give visitors the impression that this hazard is unusually serious in Horsethief Cave.

2. Visitors should be advised to traverse unstable areas slowly, carefully, and one person at a time.

3. We recommend that BLM not institute a program of prying down loose rocks or stabilizing rocks within the cave.

Difficulty of search and rescue

1. Visitors should be cautioned to be particularly careful underground since search and rescue would be difficult.

2. The search and rescue strategy for Horsethief Cave should place primary emphasis on the quick location of missing or injured visitors.

3. "In-out" registers should be established at eight or possibly nine sites within the cave.

4. BLM should institute a management program to insure that "in-out" registers are used.

Hazard of dust

1. Cave visitors should be advised to avoid unnecessary stirring up of dust in the area between the entry register and the Gypsum Wall. Visitors should travel in groups of two or three people with ten or fifteen minutes between parties.

2. The present cautioning of visitors about radioactive properties of dust should be dropped; it is a trivial issue.

Hazard of being trapped by a malfunction of the gate lock

1. A supply of hacksaw blades should be cached about 20 feet inside the cave from the gate. Visitors should be told of the location of this cache,

and should be asked to make sure that it is in place.

2. Use of magnetic locks on this gate should be continued; this type lock appears ideal for general cave gate use.

Naturally occurring alpha radiation

1. Alpha radiation should not be considered a major health and safety issue.

2. It is not necessary for BLM to caution visitors to Horsethief Cave about cave radiation. We recommend that visitors not be cautioned about this potential hazard since it is of minor significance.

3. In the event that BLM does not concur with recommendation 2, we have prepared a cautionary statement which is technically accurate and places the cave radiation issue in a perspective which enables visitors to make meaningful decisions about the potential hazard and their willingness to accept the potential risks of this hazard.

4. With respect to employees doing cave work, BLM should comply with the provisions of the precautionary cave radiation standards in Appendix C, Attachment 1.

5. The present information sheet on cave radiation hazards given to visitors should no longer be used.

6. Adequate radiation monitoring has been done in Horsethief Cave, and further monitoring is not needed.

The potential hazard of histoplasmosis

1. Histoplasmosis should not be considered a health hazard in this cave, and no warning to visitors is necessary.

2. The results of histoplasmosis culturing of samples from this cave are not yet known. When the analysis is completed, we will review the data and prepare an addendum to this report which will include any additional management recommendations warranted.

Evaluation of the adequacy of the existing cave map

1. The version of the map given to visitors is generally adequate for their use. Six minor modifications to the map are recommended.

2. The existing maps of the cave are not adequate for management purposes. The utility of the maps could be greatly improved (with a reasonable level of effort) by the preparation of a written description of the best route to each of the major areas of the cave. The written route descriptions could guide cave management or search and rescue personnel over the best routes to all of the proposed locations for "in-out" registers.

3. The written route descriptions should be used to complement the exist-

ing map; some minor improvements on the existing maps may be helpful in conjunction with the route descriptions.

Review of the 1975 safety hazards inventory

1. The inventory is of management value, and gives BLM personnel a grasp of the hazards which exist in the cave. The inventory could be helpful in search or rescue efforts.

2. The 1975 inventory is adequate for the recommended management purposes, and is reasonably accurate and consistent. Revision or modification of the inventory is not needed.

3. The inventory, or the four page document derived from it, should not be routinely given to visitors. This is because general cautioning is deemed superior to specific site cautioning in situations such as those found in Horsethief Cave.

Additional investigations

1. The impacts of surface land uses on the cave and cave features should be assessed in detail.

2. A few sample travel routes should be established in the cave to provide a "how to" example, and to introduce visitors to the travel route management concept. This work should include the development of a brief description of the resources protected by each of the sample travel route segments. In addition, draft guidelines for the establishment of travel routes should be developed.

3. A good collection of photographs depicting features and conditions in Horsethief Cave, plus explanatory narrations, should be developed to help land managers better understand the resources and management problems associated with this cave.

4. The photo points in the cave should be re-photographed and analyzed at two or three year intervals.

5. Eight (or possibly nine) "in-out" registers should be installed in the cave as a component of the safety program. Each site should be carefully selected to insure that it could not be missed or bypassed by visitors.

6. A written description of travel routes to each major area of the cave should be prepared; some minor modification of the existing maps might be needed. These materials would not be for visitor use, but instead would be used for management purposes and for search and rescue operations.

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DESCRIPTION OF HORSETHIEF CAVE

This description is designed to help in the protection and management of Horsethief Cave by giving BLM land managers a "feel" for the natural resources present. Six features of Horsethief Cave are identified which are particularly significant. These are:

1. Length and complexity of cave passages, and the great potential for additional discoveries.

2. Great diversity of cave passages and features.

3. Nature, extent, diversity, and beauty of cave mineralization.

4. Near-natural condition of the cave.

5. Paleontological and archeological values.

6. Major recreational and esthetical values.

Each of these six features will be discussed separately in the following pages of this report.

Length and complexity of cave passages, and the great potential for additional discoveries

Horsethief Cave is the longest known cave in Wyoming. Horsethief Cave connects, through a passage which was blocked to control access, with Bighorn Caverns just across the state line in Montana. The Bighorn Caverns portion of the cave system is the longest known cave in Montana (Campbell, 1978). The combined cave system represents the longest known cave in the United States west of the Black Hills in South Dakota. The presently known passage extent is in excess of ten miles, and is probably closer to 15 miles in length.

The passage network in Horsethief Cave is very complex. The cave is a maze with many parallel and nearly parallel passages. Unlike the maze of a city street system, many of the passages in Horsethief Cave do not connect with nearby passages. In a number of cases, extensive areas of the cave are accessible through only a single connecting passage. The result is a maze rather like those through which laboratory mice are run in conditioning experiments. However, in the case of Horsethief Cave, the passage configurations are all different, and the crucial connecting passages are often small, obscure holes. Horsethief Cave has one of the most complex passage networks that we have encountered in over 25 years of cave work throughout the United States. This passage complexity has substantial natural significance; it also has safety and management significance which will be discussed later in this report.

The Horsethief Cave system shows great potential for future discoveries. Quite possibly these discoveries could rival the passages presently known in this cave system. It seems likely that most of the significant new discoveries will result from persistent efforts by cavers who become

very familiar with the cave. Because of the complexity of the cave system and the vast array of known significant features, most occasional visitors to the cave likely will not be discovering new passages.

Based upon the present extent of known passages, the Horsethief Cave system is a nationally significant feature. With the discovery of additional passages, the national significance of the cave would be increased.

Chabert (1979) has published a listing of the twenty longest caves of the world. All of these caves exceed 21 miles of mapped passage. Nine of the caves on the list are in the United States. Although it is highly conjectural, the discovery of additional passages in Horsethief Cave may ultimately place this cave system on the list of the longest ten caves in the United States, and on the list of the twenty longest caves of the world.

Our beliefs on the potential extent of the Horsethief Cave system are based upon our field work in the area and our knowledge of cave development in the Madison limestone. The second longest cave in the United States (and the fifth longest in the world) is Jewel Cave in South Dakota. Approximately 60 miles of passage have been mapped in Jewel Cave. The fourth longest cave in the United States (and the ninth longest in the world) is Wind Cave, which is also in South Dakota. Approximately 30 miles of passage have been mapped in Wind Cave. Jewel, Wind, and Horsethief Caves are all developed in the Madison limestone. All three of these caves are complex maze systems, and all three of them have experienced similar hydrologic conditions during their solutional development and enlargement. Although there are important differences among these three cave systems, the similarities enhance the belief that Horsethief Cave is an extremely extensive cave system.

This discussion of the potential extent of passages in Horsethief Cave is designed to help BLM personnel appreciate the possibility of cave resources with rapidly increasing significance. Although management decisions and strategies must be based largely upon the known extent of the resource, it is important for BLM management to recognize that the known resource and its significance almost certainly will increase substantially in the future.

Great diversity of cave passages and features

Horsethief Cave is characterized by impressive diversity in the nature of passages and in the nature and extent of cave features. The diversity is such that one cannot describe a "typical" cave passage. The passages vary from small, meandering stream passages to high fissure passages, and then to chambers 500 feet long, 70 feet wide, and 30 or more feet high. Some of the chambers are totally barren of formations (speleothems). Other passages are heavily decorated with extremely delicate calcite speleothems. In some of these chambers, particularly those in the vicinity of the Mind Bender Pool, one almost feels that he has somehow become encapsulated in a huge geode. Still elsewhere in the cave, often where least expected, one finds areas with exotic gypsum formations. These include giant blocks of crystal, gypsum flowers and crusts, gypsum needles, and angel hair.

The cave also contains some paleontological materials at depth within the cave. In addition, potentially important archeological materials may occur in the entrance chamber. The paleontological and archeological materials add to the diversity of features present within Horsethief Cave; they will be discussed in detail later.

Nature, extent, diversity, and beauty of cave mineralization

Horsethief Cave contains some outstandingly beautiful and spectacular displays of cave formations. Among the calcite formations are soda straws, stalactites, draperies, helictites, stalagmites, columns, rimstone dams, flowstone, and calcite rafts. In one area of the cave (Area 5) a small depression in the floor contains hundreds of separated yellow calcite crystals. In Area 9, we found some calcite crystals almost the size of tennis balls which had fallen from small cavities in the ceiling.

Many of the stalactites in Horsethief Cave are extremely slender and delicate. The speleothems in this cave display an amazing variety of color; some are translucent to white, others yellow to orange, while others are tan and some are even black. This coloration is due to various compounds incorporated within the calcite. There are very few caves in the United States which could rival the range in colors found in the cave formations of Horsethief Cave.

Inman(1977) notes that Horsethief Cave is considered by many people to be the most decorated cave in either Wyoming or Montana. We believe that this is a correct appraisal. Furthermore, Horsethief Cave is undoubtedly one of the best decorated caves in the northern United States. Typically, caves in northern or colder climates have fewer and smaller speleothems than do caves in southern or warmer climates. Speleothem forms in northern climates are normally more slender and delicate than those in southern climates. Although speleothems are locally abundant in Horsethief Cave, and often very long, their forms are slender and delicate in keeping with the cold climate of the area. Because of this, the abundant speleothems found in Horsethief Cave are noticeably different from those which typify caves in warmer climates. As a result, the calcite cave formations found in Horsethief Cave represent a highly unique assemblage which is, in our opinion, of national significance.

Horsethief Cave also contains excellent and diverse gypsum formations. These include cave crusts, needles, massive crystals, angel hair, and gypsum flowers. The gypsum formations are beautiful, and display wide variations in form. When we think of caves with outstanding gypsum formations, we think of portions of the Flint Ridge-Mammoth Cave System in Kentucky, Fittens Cave in Arkansas, Silent River in Arizona, and now Horsethief Cave in Wyoming. It is our conclusion that the gypsum formations within Horsethief Cave are also of national significance.

From the previous descriptions, it is obvious that there is a great deal of diversity and beauty in the cave mineralization found in Horsethief Cave. Furthermore, these speleothems are of outstanding beauty. We have visited hundreds of caves in the United States and abroad, and have had ample opportunity to become jaded. Even from our perspective, Horsethief Cave has cave formations which are extremely diverse and tremendously beautiful. This is without a question one of the most beautiful caves in the United States; the cave is of national significance.

Near-natural condition of the cave

Bighorn Caverns was discovered in 1961; the majority of the Horsethief Cave system was discovered after 1970. Both entrances were gated in 1972. The connecting passage between the two cave entrances was plugged sometime prior to 1972, and before it had received much travel. Because of the relatively recent discovery of the cave system and the rapid gating of the caves, vandalism and intentional breakage or removal of cave features has been very minor.

Much of Horsethief Cave is in near-natural condition, although some degradation of the natural conditions in the cave are occurring from trampling. This problem will be discussed later in this report, and approaches will be suggested for controlling this resource degradation. During our field work, Horsethief Cave was free of trash, names on the walls, and vandalism. We saw no evidence of intentional breakage of cave formations. Accidental breakage of cave formations has occurred, but is not very obvious. Careless cavers have walked, or put muddy hands, upon cave formations in some areas, but this has not been so prevalent as to seriously damage the natural integrity of the cave.

It is our conclusion that Horsethief Cave still displays conditions which are very nearly natural. The majority of cave visitors have obviously tried to maintain the natural integrity of this cave. The near-natural conditions found in Horsethief Cave are an important facet in the overall national significance of this cave system.

Paleontological and archeological values

Horsethief Cave contains some isolated deposits of bones (such as those in Area 7 near the drill hole). Some of these bones are of Pleistocene age, while others are no more than a few hundred years old. These fossils demonstrate that entrances to this cave system have come and gone in the past. In addition, there are some excellent Mississippian age fossils (such as corals) which are exposed in the bedrock or derived from it. Some of these fossils are exquisite.

The cave may also contain some archeological deposits in the area near the entrance. Inman (1977) suggests that archeological test excavations would be needed to evaluate the significance of these materials. The assessment of archeological significance is outside our field of expertise. However, the location and configuration of the cave entrance and the chambers near the entrance would seem adequately suited to some prehistoric human use. In addition, there are several places near the entrance where water drippage occurs; water could have been an important resource in the area in prehistoric times.

Major recreational and esthetical values

One indication of the recreational and esthetic values of Horsethief Cave is the substantial visitation which it receives from people who have come great distances specifically to visit this cave. Horsethief Cave is not simply "another" cave; it is one of the premier caves of the northwestern United States.

Finding one's way through the maze of passages (and back out of the cave) is a challenging experience. The challenge is increased by the presence of some fairly small crawlways and some necessary climbing. Although the crawlways and climbs are demanding, they are neither treacherous nor particularly dangerous.

One of the major esthetic values found in the cave is outstanding beauty, and a visit to the cave is a highly exhilarating experience. Although many beautiful features are found in the area near Mind Bender Pool, other beautiful features are scattered throughout the rest of the cave.

The wildness and remoteness of the cave are also important esthetic values. Horsethief Cave possesses these characteristics in abundance.

It is our conclusion that Horsethief Cave has highly significant recreational and esthetical values, and that these values contribute to the overall significance of Horsethief Cave.

STATE AND NATIONAL SIGNIFICANCE OF HORSETHIEF CAVE

It is our conclusion that Horsethief Cave is the most singularly significant cave in the state of Wyoming, and is of both state and national significance. The descriptions in the previous section of this report are offered as justification for this conclusion. Horsethief Cave is the largest cave in Wyoming, and the longest cave in the United States west of South Dakota. Horsethief Cave is a complex system with a great diversity of cave passages and features. The cave displays extensive, diverse, and beautiful cave formations; these speleothems represent one of the very best displays of mineralization found in any cold-climate cave in the United States. The near-natural condition of the cave, its paleontological and archeological values, and its great recreational and esthetical values add to the national significance of Horsethief Cave.

The Heritage Conservation and Recreation Service, U.S. Department of the Interior, administers the National Natural Landmark program. This program seeks to identify and designate natural features which are of national significance. During the last five years, we have assessed nine caves in Missouri and Indiana for possible designation as National Natural Landmarks. One of the crucial questions in these assessments is whether or not the cave in question possesses national significance. Based upon our experience with the National Natural Landmark program, it is our unqualified conclusion that Horsethief Cave does possess major national significance. Horsethief Cave is one of the most outstanding caves in the United States. The Bureau of Land Management is to be congratulated for the attention and concern which they have given this cave.

THREATS TO THE NATURAL INTEGRITY OF THE CAVE AND ITS RESOURCES

In conjunction with our work, three categories of threats to the cave resources or to the natural integrity of the cave have been identified. These are:

1. Threats associated with mining activities.

2. Threats related to surface land use.

3. Threats associated with visitation and use of the cave.

Each of these categories will be discussed separately in the following sections of this report.

Threats associated with mining activities

Uranium mining has been conducted in the area in the past; there are several currently abandoned mines in the Little Mountain area, where Horsethief Cave is situated. In addition, some rather extensive exploratory drilling for uranium deposits has been done in the area, including some areas overlying Horsethief Cave. One of these exploratory holes passes through a cave passage in Area 7 of the cave. It is our understanding that apparently valid mining claims exist on some of the lands underlain by the Horsethief Cave system.

McEldowney et al. (1977) have described the geology of uranium deposits in the area. The deposits are associated with cave fills, speleothems, and breccia along active hydrologic systems (i.e., voids). The existing mines in the area have exploited these cave-associated deposits. In general, mining for uranium in the area represents cave excavation.

If it were to occur, uranium mining would obviously destroy Horsethief Cave. The result would be the loss of a cave and cave resources of national significance.

During our field work we conducted rather extensive alpha radiation monitoring in Horsethief Cave. Almost all of the measured alpha radiation is derived from radon daughters. The results of our monitoring are shown in Table 2.

Unless Horsethief Cave were strongly ventilated, which it is not, one would anticipate high alpha radiation concentrations to be associated with potentially exploitable uranium deposits. The alpha radiation concentrations which we measured, and those which have been measured by others, are not nearly as high as would be anticipated if there were indeed significant uranium deposits associated with the cave.

The alpha radiation concentrations in Horsethief Cave are similar to, or perhaps slightly higher than, those concentrations which typify most large cave systems elsewhere in the United States. Alpha radiation concentrations as high as 18 to 20 working levels have been recorded to Kentucky caves where no uranium mining or exploratory drilling has been conducted. Alpha radiation concentrations of tens to hundreds of working

levels are often found in worked-out uranium mines. The highest concentrations we measured in Horsethief Cave was 3.37 working levels, and the highest of record is 5.34 working levels.

Since we do not have expertise in uranium exploration or mining, it is possible that any relationship between exploitable concentrations of uranium and alpha radiation concentrations in caves is more complex than implied. However, what we are attempting to do is to point out that alpha radiation concentrations in Horsethief Cave are not unusually high, and that this may be an indication that mining in the area is not economically feasible.

Uranium mining presents a potentially very serious threat to Horsethief Cave. It is our conclusion that Horsethief Cave is a natural feature of major national significance; damage to such significant cave resources in exchange for uranium would not, in our opinion, be in the public interest. Protection of the cave resources at Horsethief Cave would most definately be in the public interest. Legal rights and questions are involved and we have no desire to enter that morass. The intention here is to encourage BLM to find some way to insure the perpetuation of Horsethief Cave, including the removal of the threat of mining.

Recommendations on threats associated with mining activities

1. Existing mining claims represent a potentially serious threat to Horsethief Cave. In view of the national significance of the cave, BLM should seriously consider the possibility of acquiring mineral rights in the area overlying and near Horsethief Cave. We have no expertise to fully appreciate how difficult this might be, but are convinced that the natural values of Horsethief Cave are so significant as to warrant the perpetual protection of this outstanding cave.

2. Alpha radiation monitoring results from Horsethief Cave may be of help in assessing the economic viability of uranium claims in the vicinity of the cave. All alpha radiation monitoring results collected from Horsethief Cave should be copied and included in the files on the mining claims in the immediate vicinity of Horsethief Cave. A copy of our comments on this issue should also be included in these files. Also recommended is an evaluation by BLM geologists of the usefulness of cave radiation measurements as an assessment tool for determining the economic potential for uranium mining in the area.

Threats related to surface land use

Caves do not constitute a world unto themselves. Rather, they are directly and intimately tied to the rest of the land in which they lie. Land use and land management actions on the surface thus affect underlying or adjacent cave passages.

Surface land use actions affect caves primarily via water. Modification of plant communities, diversion of surface waters (even by features such as roads and man-induced gullies), and impoundments can all have significant impacts on underlying and adjacent cave systems.

Presuming that the map of Horsethief Cave is reasonably accurate,

the cave underlies or nearly underlies part of the landing strip in Section 20, T58N, R94W, some well established jeep trails, two westward-flowing intermittent streams, and one man-made stock watering pond. The northern-most intermittent stream apparently provides water for the cave formations in the vicinity of Mind Bender Pool in Horsethief Cave. The landing strip crosses the headwaters of this intermittent stream, and may have altered the quantity of flow in this small basin. In addition, construction of the landing strip undoubtedly increased sediment production, and this could have adversely impacted the cave and its water regimen.

The southern-most intermittent stream shown in the NW¼ of Section 20 passes near the southern-most known portions of Horsethief Cave. A pond for stock watering has been constructed near the headwaters of this stream. This pond has changed the flow regimen of this stream, which would undoubtedly alter conditions in underlying cave passages. Although no passages are known which lay beneath this intermittent stream, it seems likely they exist. It also seems likely, in view of the extensive cave formations associated with the intermittent stream to the north, that significant cave formations could be found in passages laying beneath the southern intermittent stream.

Recommendations on threats related to surface land use

1. During 1979 field work we did not correlate surface features such as roads, the airstrip, and stock ponds with features in the underlying cave passages. This should be done in future work, since it is possible that surface features have had (and are having) adverse impacts on the cave.

2. The stock pond in the northwest quarter of Section 20 should be replaced by one outside of the cave area. The pond disrupts the natural water flow in the intermittent stream, and encourages concentrated livestock use with attendant increases in sediment production and soil compaction. All of these impacts could seriously affect underlying or adjacent cave passages. The area in the vicinity of the pond should be returned to as near-natural condition as possible, and the area should be carefully revegetated.

3. The impacts of the landing strip on the cave should be evaluated, and recommendations should be developed for mitigation of any adverse impacts which are identified. Improvements to, or reconstruction of, this landing strip should not be permitted, as such activities could harm the cave and cave features.

4. All future proposed land use activities in the north half of Section 20 should be evaluated to determine their potential impacts on the Horsethief Cave system.

Threats associated with visitation and use of the cave

Many cave resources are non-renewable, yet are readily subject to degradation or destruction. Obvious examples are speleothems, which may require tens of thousands of years to grow. They are not readily subject to restoration if they are damaged, and if they are destroyed, they cannot be replaced.

Most of the renewable resources in Horsethief Cave are experiences. Beauty, solitude, and challenges are predominantly renewable resources, although they are degraded somewhat by the total amount of use which has occurred in the past.

The cave is presently in near-natural condition. The presence of the gate, the sign-out procedure, and the information given to visitors all help in the protection of cave features. Still, visitation is having adverse impacts on the cave, and the quality of the resource is deteriorating.

Trampling is the most serious impact that present visitation practices have on the cave. In most portions of the cave, footprints are permanent features. It is obviously impossible to visit the cave without leaving footprints, however, it is totally unnecessary for the footprints to be spread over the entire floor of the cave passages. Except in areas where routes had been delineated with survey ribbon, there is no evidence that most visitors to the cave are making any effort to minimize their trampling. People have tramped through sticky red mud and tracked it for several hundred feet down passages when they could have avoided the mud and left the cave much less trampled. Too many portions of the cave are beginning to resemble a snow covered school yard after the first recess; the entire floor area is becoming covered with tracks.

The easiest way to reduce cave trampling is for all visitors to follow the same route through the cave. At least initially, this requires that travel routes be delineated. This delineation can be done with two parallel lines of white nylon cord (such as that used for stringlines in construction). Once the route gets some travel, and visitors learn to respect the cave by staying on the established routes, the stringlines can probably be removed because the route is adequately visible.

The establishment of travel routes throughout the cave would greatly reduce the impacts of present visitation. This would be a very important management action for insuring the protection of the cave and the perpetuation of its features. Looking ahead, Horsethief Cave is becoming well known to cavers throughout the United States, and visitation pressures are bound to increase. Increased use cannot be permitted to accelerate damage to this magnificent cave.

Aside from the problems of trampling, visitors to this cave have generally done an outstanding job of protecting cave features. There are some places where people have carelessly put muddy hands or gloves on formations or other cave features, but this is basically an extension of the trampling problem and warrants no additional discussion.

We have reviewed the Worland District Cave Management Plan, and in particular, the portion of the plan which relates to admission quotas. Based upon the magnitude of impacts which have occurred in this cave since the discovery of 1970, we do not believe that use greater than that recommended on pages 27 and 28 of the Cave Management Plan (BLM, 1978) would be prudent.

Horsethief Cave presently receives substantial use in conjunction with the training program of the National Outdoor Leadership School. We

question whether heavy use of cave resources of national significance in conjunction with a training program is appropriate, and whether it represents the highest and best use of basically non-renewable cave resources. It seems to us that training programs could be conducted in less significant caves. We recommend that BLM consider this issue in detail, particularly in view of our assessment that the cave and its features are of major national significance.

The history of use of wild caves on public lands in the United States has often been characterized by the "capture" of use by small user groups. In exchange for promises to screen members before permitting them in the cave, and perhaps promises for occasional maps and "scientific" reports, land management agencies have often restricted cave access to members of a particular user group. The Cave Research Foundation, which is a group of cavers, has essentially captured all wild caving opportunities in both Mammoth Cave and Carlsbad Caverns National Parks. In reality, Cave Research Foundation has become a concessionaire in these parks as they have essentially total control over visitor use of the wild cave resource.

No user group should be permitted to gain exclusive or primary use of Horsethief Cave. Neither the scientific values of the cave nor the hazards of exploration warrant this sort of approach. Although it will require management effort on the part of BLM and more wrestling with management questions such as carrying capacity, the use of the cave should be as broad as possible. This appears to be BLM's present approach, and the continuation of this strategy will not have adverse impacts on the cave or its features, and this is the reason for this discussion.

Recommendations on threats associated with visitation and use of the cave

1. Steps should be taken to curtail trampling of the floor and cave features within Horsethief Cave. The purpose of the program should be to protect cave resources while still permitting cave visitation and exploration. This management program should include the following components:

A) All visitors to the cave should be informed that trampling is causing irreversible damage to the cave and cave features, and that BLM needs the help of visitors in controlling the problem and in better protecting the cave. As a part of this program, all visitors should be asked to stay on established travel routes. The established routes should not preclude exploration.

B) Sample travel routes should be established by BLM or their contractors in a few portions of Horsethief Cave. A brief description of the resources which were protected by the travel route should be prepared for distribution to cave visitors. The sample travel routes would show visitors the value of the approach, and would provide a valuable "how to" example.

C) Based upon the sample travel routes, experienced cave visitors should be encouraged to establish travel routes elsewhere in the cave. Travel routes could be established rather quickly if each experienced party entering the cave would agree to establish a few hundred feet

of travel route on each of their visits. We recommend that BLM develop and provide some simple written guidelines for the establishment of travel routes in Horsethief Cave.

D) Travel routes should be established as soon as new portions of the cave are discovered. This would insure that future visitors would see these portions of the cave in nearly pristine condition.

E) Nylon cord of the type commonly used for stringlines in construction should be used for delineating travel routes in the cave. Cotton cord would rot and be unsightly. The cord should be used to delineate both sides of the travel route. Survey ribbon should not be used for travel route delineation because it is excessively obvious.

2. Based upon damage which has already occurred to the cave from visitor use, the carrying capacity or admission quotas established in the BLM (1978) cave management plan should not be increased. We believe that these limits are reasonable and necessary for the protection of the cave.

3. We question whether heavy use of the cave resources of national significance in conjunction with the training program of the National Outdoor Leadership School is appropriate, and whether it represents the highest and best use of basically non-renewable cave resources. We recommend that BLM consider this issue in detail, particularly in view of our assessment that the cave and its features are of major national significance.

4. Restriction of cave use to selected user groups is not necessary for the protection of the cave, cave features, scientific resources in the cave, nor for the protection of cave visitors. No user group should be permitted to gain exclusive or primary use of Horsethief Cave.

5. It is our conclusion that Horsethief Cave qualifies for designation as a National Natural Landmark. Such designation would be beneficial to BLM management of the cave resources, and would be beneficial to the protection of the cave. We recommend that BLM contact the Heritage Conservation and Recreation Service (HCRS) about the possibility of designating this site as a National Natural Landmark, and that copies of the preceding portions of this report be sent to HCRS. Information on this program can be obtained from: Heritage Conservation Recreation Service, National Natural Landmarks Program, P.O. Box 25387, Denver Federal Center, Denver, Colorado 80225.

6. A good collection of photographs depicting features and conditions in Horsethief Cave plus explanatory narrations would help BLM land managers better understand the resources and management situations associated with this cave. Such photographs should be taken and the narration prepared.

7. The photo points which have been periodically photographed provide an important index for assessing visitor impacts on the cave. We examined existing photographs, and concluded that annual re-photography is not necessary. The photo points should be re-photographed and analyzed at two or three year intervals. The last photography was in the summer of 1978.

HEALTH AND SAFETY

Eight hazards which may be associated with visitation of Horsethief Cave have been identified. These are:

1. The hazard of becoming lost either because of confusion or because of inadequate lighting.

2. The hazard of falls which result in injury.

3. The hazard of rockfall and shifting rocks.

4. The difficulty of rescue.

5. The hazard of dust.

6. The hazard of being trapped in the cave by a malfunction of the lock on the gate.

7. The presence of natural alpha radiation.

8. The potential presence of the fungus Histoplasma capsulatum.

Each of the above hazards will be discussed in detail. The above tabulation represents our assessment of the relative significance of the hazards; hazard 1 is the most significant and hazard 8 is the least significant.

The hazard of becoming lost

Horsethief Cave is a very large cave system, and one in which it is easy for people to become disoriented and lost. There is extensive rock breakdown in the cave, and to many people, one breakdown chamber looks like another. Many of the passages which connect one chamber with another are small and rather obscure. Particularly in breakdown chambers, it is very easy to "lose" the passage out.

Horsethief Cave can be characterized as a maze, and many of the passages do not connect with nearby passages. Extensive portions of the cave are accessible through only a single connecting passage, and that passage may be small and obscure. Earlier in this report we compared the cave passages to the mazes through which laboratory mice are run in conditioning experiments; this is an appropriate analogy.

The extensive portions of Horsethief Cave were discovered in 1970 (Sutherland, 1971). Within less than a year, one person was lost in the cave for 36 hours, and had to be rescued by cavers (Sutherland, 1971). In the BLM files in Cody we noted that a party of two people also became lost and required rescue a few years ago. Becoming lost and/or losing one's lights is a major hazard in Horsethief Cave.

Based upon data in the Cave Management Plan (BLM, 1978) visitation in Horsethief Cave is now limited to 400 people per year; this limit was based upon past usage. If we assume that the average trip in this cave

lasts ten hours, and that there have been 400 people per year visit this cave in the nine years since its discovery, then this represents a total of about 36,000 hours of cave use. Since at least three people have become lost and required rescue during this time, one person becomes lost for about every 12,000 hours of caving time.

Most cave rescues result from the loss or failure of lights carried by visitors. In addition, inadequate lighting often results in people becoming lost in caves. Although the hazard is generally perceived by most visitors, people commonly enter caves with lights of inadequate quality and without an adequate supply of spare lights.

Horsethief Cave is not the sort of cave where one could fumble around in the dark and find his way out. The cave is far too large and complex for this to be possible unless one were very near the entrance. All visitors to Horsethief Cave should be specifically and strongly cautioned to carry adequate lights of good quality.

Caving literature commonly recommends that people carry three independent sources of light. The shortcoming of this recommendation is that it does not specify the quality of lights. Better guidance is that each person should carry at least two sources of acceptable light. Candles, chemical light-sticks, matches, lighters, flashlights with undependable switches, flashlights with batteries smaller than size D and gasoline, propane, or kerosine lanterns should not be counted as lights (although some of these items are sometimes nice to carry). In addition, each flashlight should have new, and preferably long-life type, batteries. Extra new batteries (long-life type) should be carried for at least half of the flashlights in the group.

Carbide lamps (with tip cleaners and spare carbide and water) are significantly more dependable than flashlights. For trips of less than 12 hours, rechargeable Wheat or MSA type battery pack lights are more dependable and provide more light than carbide lamps. Spare parts and repair materials are always prudent.

Management recommendations dealing with the hazard of becoming lost

1. BLM cave management strategies should view people becoming lost as the most significant safety hazard in Horsethief Cave.

2. BLM's present recommendation to visitors that they place removable ribbons on their way into the cave, and remove them on their way out, is a prudent approach and should be continued.

3. All visitors should be cautioned that, in this cave, becoming lost is a real hazard.

4. All visitors should be advised to carry at least two sources of acceptable light. Candles, chemical light-sticks, matches, lighters, flashlights with undependable switches, flashlights with batteries smaller than size D and gasoline, propane, or kerosine lanterns should not be counted as lights (although some of these items are sometimes nice to carry). In

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The hazard of falls which result in injury

Horsethief Cave is basically a horizontal cave system, and it does not have many pits or climbs (in distinct contrast to Spirit Mountain Caverns and La Caverna de los Tres Charros). There are places where one must climb over breakdown blocks. One climb in the cave which cannot be avoided is the Gypsum Wall, at the boundary between Areas 2 and 3. At the Gypsum Wall (on the way into the cave), one climbs about 20 feet down a steeply inclined wall. Handholds and footholds are abundant, and the climb is not particularly difficult. However, an inexperienced, youthful, or awkward person could fall on this climb. If such people are included in a group, it is advisable to carry at least 40 feet of belay rope.

There is a large slab separation about seven feet from the base of the Gypsum Wall. If a person fell on this climb, he could easily break a leg.

Travel through Horsethief Cave requires a great deal of scrambling across breakdown blocks. Falls are likely to occur during such activities. Most such falls are not serious, but they always hold the potential for debilitating injury.

Although falls may occur in the cave, they will generally not be serious. The hazards of falling are no more serious in Horsethief Cave than in most caves. During our field work, no places were found which were particularly treacherous with respect to the hazard of falls.

Management recommendations dealing with the hazard of falls which result in injury

1. With respect to this hazard, there are no areas in the cave which are particularly hazardous; this should be recognized in BLM's cave management strategy.

2. Visitors to Horsethief Cave should be cautioned to be particularly careful about their footing, and to be particularly careful on climbs, because rescue of an injured person from this cave would be extremely difficult.

3. If parties contain inexperienced, youthful, or awkward persons, they should be strongly encouraged to carry at least 40 feet of belay rope for the decent of the Gypsum Wall. Most people visiting this cave would not find a belay rope necessary, and there is no reason to encourage them to take a rope into the cave.

The hazard of rockfall and shifting rocks

As indicated in the 1975 inventory for Horsethief Cave (Appendix A), there are a number of areas in the cave where there are loose rocks, shifting rocks, or where the passage is unstable. These areas are generally obvious to people visiting the cave.

There are several places in the cave where one must very carefully pick his way through loose rock areas. There are a few crawlways where loose rocks are encountered on the walls, floors, and ceilings. Of these areas, one of the least stable is in Area 9 of the cave; the area is on the HA survey line and is known as the Nervous Breakdown. This crawl must be traversed slowly, carefully, and by one person at a time. With reasonable care, the area can be safely traversed. This crawlway does not warrant closure of this area to visitation.

The hazards associated with rockfall and shifting rocks are not unique to Horsethief Cave, but are instead similar to conditions found in most cave systems. Visitors should be cautioned about this hazard, but such cautioning should not give visitors the impression that the hazard is particularly serious in Horsethief Cave as compared with other caves.

Management recommendations dealing with the hazard of rockfall and shifting rocks

1. Visitors to Horsethief Cave should be cautioned that caves (including this one) often have unstable ceilings, walls, and floors, and that visitors should carefully watch for such areas. This cautioning is prudent for all caves; care should be taken to not give visitors the impression that this hazard is unusually serious in Horsethief Cave as compared with other caves.

2. Visitors should be advised to traverse unstable areas slowly, carefully, and one person at a time.

3. We recommend that BLM not institute a program of prying down loose rocks or stabilizing rocks within the cave. It is our conclusion that risks to cavers or employees doing such work would be greater than any resulting improvement in visitor safety.

The difficulty of search and rescue

The difficulty of search and rescue as a hazard is included in our consideration of health and safety issues in Horsethief Cave because it compounds some of the other identified hazards. Rescue of a seriously injured person from this cave would be an arduous and difficult matter. There are a number of places where it would be impossible to move a person in a litter through the passages. In the case of something like a spinal injury, it might be impossible to get the person out of the cave through existing passageways.

There are many caves where rescue problems would be as difficult as those found in Horsethief Cave. Although land managers worry about the possibility of elaborate rescues, such rescues seldom occur. In the case

of Horsethief Cave, most rescues are likely to be minor, and the victim will probably be able to assist in his removal. The prudent approach is to develop search and rescue strategies designed to cope with the types of mishaps which are most likely to occur. In Horsethief Cave, these are lost cavers and cavers with injuries no greater than broken limbs. Any serious accident will require a specific strategy developed for that one occasion.

It is our conclusion that search efforts in Horsethief Cave will substantially outnumber rescue efforts; this has been the situation to date. Good search efforts require good organization, people who follow instructions, and a good search strategy. Although cavers familiar with the cave can be of great value in a search, search efforts should not be delayed until such help can arrive.

Under present conditions, the entire cave might have to be searched in order to find a lost party. This could consume a great deal of time and delay needed rescue. Furthermore, there is always the possibility under current conditions that a party could have left the cave and become lost elsewhere, or merely not checked in with BLM following the trip.

One way of greatly simplifying search efforts in the cave would be to establish a number of "in-out" registers in major connecting passages in the cave. People passing an "in-out" register would sign the register on the way in and sign it again on the way out. With such a system, it would be possible for one or two small rescue parties to rapidly visit the registers and determine which portion of the cave the missing people were in. Placement of one of these "in-out" registers near the present register would make it possible for one BLM employee with a flashlight to determine whether or not a missing party was even in the cave.

For the "in-out" registers to work, it would be necessary for people to always sign them. Most cave visitors would do this if the reason for the registers were explained to them, and many cavers would appreciate the fact that the registers would greatly decrease the size of a search effort and the impacts of such an effort on the cave and its features. The register sheets could be periodically inspected for sign-in and sign-out compliance; those who did not comply could be barred from the cave for awhile or handled in some other appropriate manner.

Based upon our field work in the cave, "in-out" registers should be installed at the following locations:

1. At the present register (about 400 feet from the cave entrance). This register could be quickly and easily checked to make sure that a missing party was actually in the cave..

2. Top of the Gypsum Wall between Areas 2 and 3. This register could be checked frequently during a search to make sure that a missing party had not left the cave. This site would also serve as a back-up for register #1.

3. Passage between Areas 3 and 4. The register should probably be on the Area 4 side of this passage.

4. Passage between Areas 3 and 5.

5. Passage between Areas 6 and 7. This register should be near radiation monitoring station 16. Visitation of Area 7 is restricted, so this register would seldom be used. Under most search conditions, this would be the last register to be checked.

6. Between Areas 6 and 8. This register should be placed at the bottom of the Crack Where the Water Comes Down (so a search party would not have to climb to the top merely to check the register).

7. Passage between Areas 8 and 9.

8. Within Area 5. A site just east of survey station F23 might be suitable. An alternate would be two registers; one would be about 150 feet west of F23, the other would be at the entrance to Montana Maze north of F23. If two registers were used, both would have to be checked to determine if a party were within the Montana Maze.

With experience and additional exploration, more registers might be needed. However, the eight (or nine) sites recommended would be an excellent start. It is important that the registers not be so common as to discourage their use. With the recommended registers, a search could be narrowed to 15% or less of the cave by one search party in less than three hours.

Management recommendations dealing with difficulties of search and rescue

1. BLM should impress on visitors that search and rescue efforts would be difficult should they be necessary. Visitors should be cautioned to be particularly careful underground.

2. The search and rescue strategy for Horsethief Cave should place primary emphasis on the quick location of missing or injured visitors.

3. "In-out" registers should be established at eight or nine sites within the cave. The recommended locations are described in the preceding section of this report, and will not be repeated here.

4. If the "in-out" registers are to work, visitors must always sign them. BLM should institute a program to insure that such registers are used. This program should include:

A) Adequate explanation of this program to all visitors.

B) Visitor cooperation with this program should be a requirement for visiting this cave.

C) The location of registers should be shown on the handout map given to cave visitors.

D) BLM should periodically examine registers from the cave to determine the effectiveness of the system, and to identify visitors who are not complying with the program.

The hazard of dust

Crawlways between the entry register and the Gypsum Wall are low, and some of them are very dusty. A very fine dust is easily stirred up by crawling through the passages. The dust is undoubtedly bothersome to all visitors, but could be particularly hazardous to asthmatics or people with respiratory problems. The dust also coats glasses, gets in your eyes, and could create some problems for wearers of contact lenses.

Some people have suggested that radioactive particles could be attached to the dust, and might thus be harmful to the lungs. Based upon our assessment, this is an insignificant hazard.

Dust problems can be minimized by careful travel through this portion of the cave, and by dividing groups into parties of two or three people. Ten or fifteen minutes should be allowed between parties to permit dust to settle and the air to clear.

Management recommendations dealing with the hazard of dust

1. Significant dust problems exist only in the area between the entry register and the Gypsum Wall. Cave visitors should be advised to avoid unnecessary stirring up of dust in this area. In addition, visitors should be advised to travel in groups of two or three people with ten or fifteen minutes between parties.

2. The present cautioning of visitors about radioactive properties of dust should be dropped. Any potential radioactivity in the dust is a trivial issue.

The hazard of being trapped in the cave by a malfunction of the lock on the gate

During our field work we had one rather protracted discussion with the lock on the cave gate; it did not wish to open and let us out of the cave. Ultimately the lock, which apparently had become partially jammed with dust, was opened. However, the incident induced wonder at what we would have done if the lock had remained jammed. Alternately, we wondered if the lock could be jammed by unauthorized people using large magnets or other devices on the magnetic lock.

Management recommendations for preventing entrapment by a gate malfunction

1. A supply of hacksaw blades should be cached about twenty feet inside the cave from the gate. These could be used in the event that a lock could not be opened from the inside. Cave visitors should be told of the location of this cache, and should be asked to make sure that it is in place.

2. The use of magnetic locks on this gate should be continued, and this type of lock is recommended for general use on cave gates.

Naturally occurring alpha radiation

A detailed discussion of the cave radiation issue (which includes an assessment of the risk, recommendations for management actions, and existing National Caves Association precautionary health standards for alpha radiation exposure in caves) is found in Appendix C. We suggest that this information be read before reading the detailed information included below on Horsethief Cave.

During the course of our field work, alpha radiation concentrations were measured at 29 stations in Horsethief Cave. The station locations are described in Table 1. Stations 1 through 25 were established in 1977. Stations 26 through 29 were established in conjunction with our field work, and had never been monitored prior to 1979. All monitoring stations were at locations prescribed in the contract documents.

The radiation monitoring stations appear on the large scale maps of the cave on file at the Worland BLM office. They are also shown on the contract documents prepared by BLM. These maps all provide adequate locational information for these stations. However, to prevent any possible confusion, the sample locations are shown on the map in Figure 1*.

Table 2 summarizes temperature and alpha radiation measurements made in 1979 in Horsethief Cave. Alpha radiation from radon daughters ranged from a low of 0.24 working levels at station 25 to a high of 3.37 working levels at station 10. The mean concentration was 1.03 working levels. In 1979, 69% of the sampling stations had concentrations of less than 1.00 working levels, 24% of the stations had concentrations between 1.00 and 1.99 working levels, and only 7% of the sampling stations had concentrations in excess of 2.00 working levels.

Although it was not required under the terms of the contract, alpha radiation from thoron daughters was also monitored at 11 of the 29 monitoring stations. Values obtained ranged from 0.000 to 0.05 working levels; the mean was 0.01 working levels. This confirmed earlier conclusions that alpha radiation from thoron daughters was insignificant in this cave.

Slight air currents could be detected at most of the radiation monitoring stations in Horsethief Cave. However, since the cave is a maze with many interconnections which could be traversed by airflows, at most places there is no way of telling whether airflow is actually in or out of the cave. For this reason, we did not record the direction of airflow. The important observation about airflow is that the cave does have natural ventilation.

Air temperatures in the cave ranged from 44 to 55 degrees F; the mean temperature was 51.8 degrees. The most commonly recorded temperature was 52 degrees.

At least some alpha radiation monitoring has been conducted annually in Horsethief Cave since 1975. Table 3 summarizes all of the collected values for radon daughter alpha radiation. The station numbers which are used are those shown in Figure 1. A few measurements were taken in the early years near the entrance to the cave and at stations which are no

* Figure 1 is found in an envelope at the back of the report.

Table 1

Description of Horsethief Cave radiation monitoring stations

Station	Location and nearby survey stations
1	Register
2	Big Fissure (A-25)
3	Gypsum Wall (C-5)
4	Big Red Buddah (C-25)
5	C-17-R
6	C-52
7	Flower Shop
8	F-1
9	F-13
10	F-18
11	Twin Totems (F-26)
12	Powder Mountain (SS-14)
13	Lily Pad Pool (SS-2)
14	Dinasaur Back (F-31)
15	Near Mindbender Pool (D-9)
16	Lee's Loop (D-61)
17	K-6
18	K-17
19	Drill Hole (D-27)
20	Flowstone River (D-13)
21	Bottom of Crack Where the Water Comes Down
22	Near H-14
23	New Flowstone (H-2)
24	Bone Pile (J-4)
25	Mud Flats (H-30)
26	Station established in 1979; survey station number illegible; the station is one station south of HA 50 in area 9
27	Station established 1979; survey sta. HA58, area 9
28	Station established 1979; survey sta. L12, area 7
29	Station established 1979; Northeast Extension of area 4. Survey station number unknown; the point is approximately 260 feet east of station C-45 (true distance, not passage distance).

Table 2

Results of alpha radiation and temperature monitoring in Horsethief Cave in 1979. Radiation values for radon and thoron daughter products and for total radiation are in working levels. Temperatures are degrees F.

Station	Date	Time	Radon	Thoron	Total	Temperature
1	8/30	1032	0.85	-	-	44
2	8/30	1051	0.62	-	-	50
3	8/29	1146	0.99	.002	0.99	52
4	8/30	1211	0.60	.01	0.61	55
5	8/26	1337	1.57	-	-	52
6	8/26	1423	1.95	-	-	53
7	8/26	1512	1.96	-	-	52
8	8/30	1442	1.07	.002	1.07	52
9	8/30	1416	2.90	-	-	52
10	8/30	1403	3.37	-	-	52
11	8/30	1346	1.46	.000	1.46	52
12	8/30	1536	0.64	-	-	52
13	8/30	1553	0.79	-	-	52
14	8/30	1245	0.62	-	-	52
15	8/30	1613	0.61	-	-	52
16	9/1	1827	0.64	.003	0.64	54
17	9/1	1930	1.85	.05	1.90	52
18	9/1	1952	0.76	.01	0.77	52
19	9/1	2010	0.75	-	-	52
20	8/30	1745	0.49	.01	0.50	51
21	8/30	1710	0.87	-	-	51
22	9/1	1220	0.44	.01	0.45	50
23	9/1	1307	0.50	-	-	52
24	9/1	1241	0.43	.01	0.44	51
25	9/1	1333	0.24	-	-	52
26	9/1	1651	0.52	-	-	52
27	9/1	1635	0.54	-	-	52
28	9/1	2033	0.64	.003	0.64	53
29	8/26	1608	1.29	-	-	53
Mean			1.03	0.01		51.8

Table 3

Summary of radon daughter alpha radiation measurements in Horsethief Cave for the period from 1975 through 1979. All values are in working levels.

	1979				1978		1977	1976		1975	
Sta.	8/26	8/29	8/30	9/1	8/8	8/10	7/13	6/30	7/1	12/12	Mean
1			0.85		0.23	1.22	1.08		1.80		1.04
2			0.62		0.72	2.45	2.20		2.60	0.50	1.52
3		0.99			2.05	1.31	1.69		1.00		1.41
4			0.60		1.40						1.00
5	1.57				1.88	1.03	2.92				1.85
6	1.95					0.46	3.09		2.00		1.88
7	1.96						2.70				2.33
8			1.07			3.07	4.01		4.40		3.14
9			2.90			5.34	3.47		3.90		3.90
10			3.37			3.05	2.90		2.60		2.98
11			1.46			1.68	1.92		2.10		1.79
12			0.64			1.90	2.00		2.00		1.64
13			0.79				2.15		2.10		1.68
14			0.62		1.68	2.08	1.95		1.80		1.63
15			0.61		1.52	1.64			2.00		1.44
16				0.64		2.27	2.08		1.80		1.70
17				1.85		2.39	1.78				3.01
18				0.76		2.09	1.18		1.20		1.31
19				0.75		0.75	1.49		1.40		1.10
20			0.49		0.44		3.65	1.20	1.60		1.48
21			0.87		1.08		1.59	1.40			1.24
22				0.44	0.60		0.81	0.59			0.61
23				0.50	0.66		0.96	0.57			0.67
24				0.43	0.36		0.86	0.35			0.50
25				0.24	0.38		0.66	0.32			0.40
26				0.52							0.52
27				0.54							0.54
28				0.64							0.64
29	1.29										1.29

mean 1979 = 1.03 1978 = 1.59 1977 = 2.05 1976 = 1.67 1975 = 0.50

mean of all observations = 1.54

longer monitored and for which no station numbers have been established. These results are not included in Table 3.

For the period 1975 through 1979, a total of 104 radon daughter measurements have been made in the cave. The mean concentration has been 1.54 working levels; values have ranged from a low of 0.24 working levels to a high of 5.34 working levels. 37% of the values are less than 1.00 working level , 28% are between 1 and 2 working levels, and 35% exceed 2 working levels.

Mean concentrations for the period from 1976 through 1979 have varied by a factor of about two; 1977 had the highest mean concentration (2.05 working levels); 1979 had the lowest mean concentration (1.03 working levels). A possible explanation for this may be related to air exchange between the surface and the cave. If sufficient surface temperature data for the period of record were available (they are not) they would probably show that alpha radiation concentrations in the cave increased with increases in surface temperatures. When surface temperatures exceed cave temperatures, the exchange of air between the surface and the cave is impeded, and the degree of impedence increases with increases in surface temperature.

Surface temperatures were cool during our 1979 monitoring; this may explain the somewhat lower than average summer values which we obtained. Furthermore, if our inferences are correct, alpha radiation concentrations in Horsethief Cave are probably substantially lower during the cool and cold weather periods of the year. Based upon the monthly cave admission quotas established in the Cave Management Plan (BLM, 1978), 65% of allowable cave visitation occurs during the period from September through May (which we class as cool or cold weather periods). With the exception of one measurement made in 1975 (which was the lowest value on record for that station) only one of the 104 alpha radiation measurements has been made when the weather was cold.

Concern about alpha radiation concentrations in Horsethief Cave has consumed a great deal of BLM's cave management efforts. In view of the anticipated differences between warm and cool periods of the year, it appears likely that the mean concentration of alpha radiation to which cavers have been exposed has been greatly over-estimated due to the fact that almost all measurements have been made under warm-weather conditions. Previous monitoring efforts in the cave have missed the management significance of this, which is that using only summer data makes the radiation issue appear of greater concern than is the actual case.

Management recommendations on hazards of naturally occurring alpha radiation

1. Alpha radiation should not be considered a major health and safety issue in Horsethief Cave.

2. In view of the existing precautionary cave radiation standards for employees of show-caves and decisions by other federal agencies that visitors need not be warned about cave radiation at caves like Mammoth and Carlsbad, we do not believe it is necessary for BLM to caution visitors to

Horsethief Cave about cave radiation. We recommend that visitors not be cautioned about this potential hazard since it is of such minor significance.

3. Since some individual visitors spend many hours in Horsethief Cave, we realize that BLM may not concur with our recommendation that visitors not be cautioned about the potential hazard of natural alpha radiation. In the event that BLM makes this decision, the following suggested cautionary statement has been prepared. This statement is technically accurate and places the cave radiation issue in a perspective which enables visitors to make meaningful decisions about the potential hazard and their willingness to accept the potential risks of this hazard.

Natural alpha radiation is derived from the atomic decomposition of uranium and thorium. Since there are minute quantities of these materials in all soils and rocks, natural alpha radiation concentrations can be measured on the surface of the land, in buildings, and in basements and caves. Caves typically have higher alpha radiation concentrations than basements or buildings. Concentrations measured in Horsethief Cave are similar to those found in other large cave systems elsewhere in the United States.

Exposure to alpha radiation in mine air has been correlated with an increase likelihood of lung cancer. Of course, the quality of cave air and mine air are different. Even though a study of cave employees working for the National Park Service did not find any correlation between working in caves and lung cancer, it is still possible that working in (or visiting) caves may present a minor hazard.

Using rule-of-thumb values calculated for miners and radiation concentrations measured in Horsethief Cave in the summer (when the concentrations are probably at their highest levels), there should be about one extra lung cancer for every 1,100,000 hours spent in this cave. Some lung cancers will be curable.

Based upon national highway fatality statistics, there are approximately 3.4 fatalities in the United States for every 100 million passenger miles. The calculated risk of lung cancer from an hour spent in this cave under summer conditions is roughly equal to the risk of death in a traffic accident on a trip of 25 miles.

Cigarette smoke increases the potentially harmful effects of natural alpha radiation. For this reason, and also to protect cave features, we ask that you not smoke while in the cave.

The above information is given to you so that you may make an informed decision about visiting Horsethief Cave.

4. With respect to employees doing cave work, BLM should comply with the provisions of the precautionary cave radiation standards in Appendix C, Attachment 1.

5. The present information sheet on cave radiation hazards given to visitors (W-01-6227-6, page 1 of 10/77) contains inaccuracies, is no longer relevant, and we recommend that it no longer be used. The comments on radiation exposure in drinking water are in error; analysis results from cave waters show radium 226 concentrations well below the federal limits for drinking water. The federal air exposure limits mentioned in the handout apply only to workers in radiation industries; they do not apply to the general public nor to workers in a non-radiation industry. The only national cave radiation standards in force are the national concensus standards of the National Caves Association; a copy of these standards is attached to Appendix C.

6. Adequate radiation monitoring has been done in Horsethief Cave, and further monitoring should not be conducted.

The potential presence of the fungus Histoplasma capsulatum

Histoplasmosis is a lung disease associated with inhaling spores of the fungus Histoplasma capsulatum. Although infection is common (Craigle, 1976), there is generally either no detectable illness or only mild respiratory symptoms. However, there is a progressive type of the disease which is often fatal; this most commonly involves an intensive exposure to the spores of Histoplasma capsulatum.

Histoplasmosis is endemic to certain areas of the United States, and in some tropical regions as well. Positive histoplasmin skin tests indicate that 80% of the population in the Mississippi-Missouri-Ohio River Valleys have been affected (Craigle, 1976). In contrast, Histoplasma capsulatum has to date been reported at only one site in Wyoming. The site is Spirit Mountain Caverns.

Because histoplasmosis is of significant concern at Spirit Mountain Caverns, it was considered in detail in our report on that cave (Aley and Aley, 1979). A copy of the histoplasmosis discussion from the Spirit Mountain report is incorporated as Appendix B in this report on Horsethief Cave; readers wishing detailed information on this disease should consult the appendix.

Spores of Histoplasma capsulatum have been found only in association with bird droppings and bat guano (Aley and Aley, 1979). They have apparently never been found in packrat droppings. In conjunction with our investigations in Horsethief Cave, we collected two samples for histoplasmosis culturing from within the cave.

Sample W-9 was collected from a packrat midden between radiation stations 2 and 3 (Table 1). The collection site was in the western end of the Buddah Room located west of the Gypsum Wall.

Sample W-12 was collected from what may be some very old bat guano. The collection site was located between radiation stations 16 and 17 (Table 1). The collection site is in the western portion of cave Area 7. This area is closed to general travel.

No other potentially suitable sites were found for the collection of histoplasmosis samples. The samples were given to Mr. Wayne Holm of the

Cody office of BLM for shipment to the Center for Disease Control, U.S. Public Health Service, Atlanta, Georgia. Once the results are obtained, they will be analyzed and an addendum prepared to this report in which any management actions which appear prudent will be recommended. It is anticipated that the samples will be negative for Histoplasma capsulatum; if this is the case, then no management actions are necessary, and there is no reason to caution visitors to Horsethief Cave about this possible hazard.

Management recommendations on the hazard of histoplasmosis

Since there is little bat guano in this cave, and no bird guano, it seems unlikely that histoplasmosis will successfully be cultured from samples collected in Horsethief Cave. Based upon the information available, the following management actions are recommended:

1. Histoplasmosis should not be considered a health or safety hazard in this cave, and no warning to visitors is necessary.

2. The results of Histoplasma capsulatum culturing of samples collected in this cave are not yet known. When this analysis is completed by the Center for Disease Control (CDC), the data will be reviewed and an addendum to this report prepared. This addendum will include any additional management recommendations warranted by the CDC data.

EVALUATION OF THE ADEQUACY OF THE EXISTING CAVE MAP FOR VISITOR USE AND SEARCH AND RESCUE OPERATIONS

The existing map of the cave which is given to visitors is generally adequate. Maps given to visitors need not be detailed, since exploration and discovery are important parts of a cave visit. However, we recommend that the map be revised to show the following:

1. Area 4 should be shown on the map.

2. Boundary lines should be drawn completely around each area. As presently drawn, the map tends to indicate where connections to other areas are located. In the case of Area 7, this is not desirable.

3. Elsewhere in this report the establishment of travel routes in the cave were recommended. Travel throughout the cave should be restricted to travel routes. If these recommendations are adopted, the map should be appropriately changed.

4. Elsewhere in this report the establishment of "in-out" registers was recommended. Their locations should be shown on maps given to visitors.

5. Area 7 is closed to general visitation because of delicate formations in the connecting passages in Area 6. We agree that Area 7 should not be shown on the map. Areas 8 and 9 should be re-numbered on the general public map to further protect Area 7. With the present numbering system, it is fairly obvious where Area 7 is actually located.

6. The notation that Area 5 is a radiation monitoring area should be deleted. See management recommendations on hazards of naturally occurring alpha radiation.

Horsethief Cave is complex, and mapping is slow and arduous. We appreciate the amount of effort which has gone into the existing mapping. However, the existing maps of the cave are not adequate for management purposes. These management purposes can range from investigations such as those we conducted to search and rescue operations.

A major problem with the management use of this map is that it fails to show all of the side passages. In many cases, a passage wall is shown as a solid line even though there are many side passages. Because of this, it is often hard for a person not intimately familiar with this cave to find his way to an area even with the map in hand.

The map also has very few cross sections, and little detail to indicate the height and traversability of particular passages. With the existing map, one cannot distinguish between an easy walking passage and a nasty crawlway. Not only does this frustrate efficient travel, but it also makes it difficult to know what sort of passage you are searching for when you are near a crucial intersection.

In a search or rescue situation, the existing map would be of great benefit, but not of as much benefit as a map which better depicted the cave.

There are two approaches which could be used to improve the usefulness of the map for management (including search or rescue) purposes. The first approach would be to modify the existing map by indicating passage heights and intersections with side passages. This would require a substantial amount of time since essentially all of the cave would need to be visited, and there are many unmapped or poorly mapped passages.

The second approach would be to prepare a written description of the route to each of the proposed locations for "in-out" registers recommended for the cave. This description would be used to complement the existing map; some minor improvements on the existing map might also be made in conjunction with the preparation of this route description work. With such a written description, a person unfamiliar with the cave could efficiently travel to any of the areas in the cave.

The preparation of a written description of travel routes to each of the major areas of the cave would be the easiest and most cost effective way of improving the management utility of the existing cave map, and this work should be conducted as soon as possible.

Recommendations for improving the management usefulness of the existing cave map

1. The existing maps of the cave are not adequate for management purposes. However, the utility of the maps could be greatly improved with a reasonable level of effort by the preparation of a written description of the best route to each of the major areas of the cave. The written route

descriptions should be prepared to guide cave management or search and rescue personnel over the best routes to all of the proposed locations for "in-out" registers.

2. The route descriptions should be used to complement the existing map; some minor improvements on the existing maps may be helpful in conjunction with the route descriptions.

REVIEW OF 1975 SAFETY HAZARDS INVENTORY

The 1975 safety hazard inventory, prepared by BLM cave rangers, is included in Appendix A. Based upon our field work in 1979, the inventory is reasonably accurate and consistent. Our work did not disclose any additional hazards which warranted inclusion on this inventory.

The hazard inventory is summarized in the cave hazard information sheets given to cave visitors. A copy of this handout (form W-01-6227-6) is included in Appendix A.

The inventory is obviously of management value. However, giving such a detailed listing to visitors is not particularly helpful to them, and may actually create problems.

The listing is so extensive that it loses usefulness. We doubt that more than a handful of visitors ever take the list into the cave with them, and unless this is done, the list is not particularly helpful. Furthermore, most of the hazards listed are obvious, and do not warrant specific identification.

Although the list identifies hazards, it does not recommend approaches which visitors can use in dealing with them. Cautionary information needs to include hazard identification and approaches for dealing with hazards.

Although the list appears to be very inclusive, it is not. It is quite possible that people could be injured in areas which are not listed. An injury in an area not shown on the hazard inventory handout could possibly lead to litigation problems.

Visitors to Horsethief Cave should receive general cautionary information. This information should identify types of hazards, and should recommend approaches for dealing with them. The cautionary information should not attempt to identify every example of a particular hazard found in the cave; the only exceptions would be cases where there were only a few examples of a particular hazard, or where a few examples were unusually treacherous.

The above approaches have been used in developing our recommendations on various health and safety hazards in Horsethief Cave. As an example, visitors to Horsethief Cave should be cautioned that caves (including this one) often have unstable ceilings, walls, and floors, and that visitors should carefully watch for such areas. Unstable areas should be traversed slowly, carefully, and by one person at a time. This provides better guidance than does the present listing of 30 unstable areas in the cave (when there are undoubtedly many more unstable areas than this).

Recommendations for future use of the 1975 hazards inventory

1. The hazard inventory is of management value, and can give BLM personnel a grasp of the hazards which exist in the cave. The inventory could be helpful to personnel directing or involved in search or rescue efforts. The inventory should be used for these purposes.

2. The 1975 inventory is adequate for those management purposes recommended, and is reasonably accurate and consistent. Revision or modification of this inventory is not needed.

3. The inventory should not be routinely given to cave visitors. This recommendation applies both to the original form of the inventory and to the form now incorporated in the four page document W-01-6227-6 (Appendix A). Our rationale was discussed in the previous section of this report. We emphasize that our concern is not with the inventory itself, but rather with the use of the inventory.

RECOMMENDATIONS FOR ADDITIONAL INVESTIGATIONS

This section of the report identifies additional management-oriented investigations recommended for Horsethief Cave. These recommendations have been discussed elsewhere in this report, but are incorporated here to provide a summary and to assist BLM in work planning.

The following work is recommended:

1. The impacts of surface land uses on the cave and cave features should be assessed in detail. This would involve investigations both on the surface and in the cave.

2. A few sample travel routes should be established in the cave to provide a "how to" example and to introduce visitors to the travel route management concept in the cave. This work should include the development of a brief description of the resources protected by each of the sample travel route segments. In addition, draft guidelines for the establishment of travel routes should be developed.

3. A good collection of photographs depicting features and conditions in Horsethief Cave, plus explanatory narrations, would help BLM land managers better understand the resources and management problems associated with this cave. Such photographs should be taken and the narration prepared.

4. The photo points in the cave should be re-photographed and analyzed at two or three year intervals. The last photography was in the summer of 1978.

5. Eight (or possibly 9) "in-out" registers should be installed in the cave as a component of the safety program. Each site should be carefully selected to insure that it could not be missed or bypassed by visitors.

6. A written description of travel routes to each major area of the cave should be prepared; this work might also include some minor modification of the existing cave map. These materials would not be for visitor use, but instead would be used for management purposes and for search and rescue operations.

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APPENDIX A

1975 BLM Hazard Inventory for Horsethief Cave, and
Cautionary Information for Cave Visitors

H.T.C. HAZARD INVENTORY & RESCUE 1975

AREA I

1. Breakdown (fresh) from ceiling
2. Thick Dust in Crawlways.

AREA II

1. Loose rocks at top of fissure and overhanging small leads.
2. 20' to 40' exposure if chimeying to top of fissure.
3. Thick dust on Denies' Crawl.
4. Crawl has tight constrictions and may have an adverse psychological effect, especially on inexperienced cavers.
5. Loose breakdown on ceiling and floor in the Red Buddha Rm.

AREA III

1. 20' drop (free climb) on gypsum crust.
2. Debris fall from ceiling holes adjacent to Gypsum Wall.
3. Possibility of alternate evacuation route on shorter vert. section of the wall.
4. Bottom wall may make good search rescue base. (Last large room before branching passages begin)
5. Loose breakdown in many areas (Difficulty in moving a litter)
6. Litter may be moved over the dogleg w/some minor passage enlargement. Bypass may exist but not for litter.

AREA V.

1. Loose breakdown near dogleg.
2. Chimney thru breakdown 10'-30' exposure and other areas.
3. Slippery old flowstone (F28 &F30) can be avoided.
4. Some breakdown covered with clay mud is extremely slick (F22-23 and other scattered areas)

5. Adjacent mazes along N. wall in the areas of F28-F18 & F1, along S. wall in area of F6.
6. Chimneying beyond end of "F" Survey involves great exposure and loose rock.
7. Montana Room and Fissure - Great quantities of lg. loose breakdown everywhere.
8. Loose Breakdown all around in Mt. Maze.
9. Maze may disorient cavers.
10. (E1-E5) (E Survey-general) Loose breakdown mostly on floor.
11. (E20) White Buddha - Loose breakdown - walls and ceiling.

AREA VI. (Pwdr Mt. to Lilly Pad Pool)

1. Minor loose breakdown ceiling & walls in fissure near Powder Mt.
2. Delta Buddha - Loose breakdown slope & loose dirt.
3. White Dirt Maze 1600' of crawlway which tends to disorient cavers.

AREA VII

1. Loose breakdown D64-K15 also other areas.
2. Extremely loose breakdown W. of ~~K15~~ K17, S. of K31 very large blocks.
3. Maze between K26-L6 fissures, crawls, and spongework.
4. 20' exposure crossing some breakdown blocks (L6)
5. Very large loose breakdown near K32.
6. Very unstable breakdown floor in Prattfall Hall.
7. Phyreatic Mazes along N. side of "L" survey. (L1)(L11)(L23)

AREA VIII

1. V. large loose breakdown on floor & sides SE of H-14-16.
2. Up to 20' exposure in chimneys and on Lg. Breakdown.

AREA IX

1. Dangerous loose breakdown is found southeast of H33. Lg. loose breakdown E of H36 and S. of H34.
2. Loose breakdown crawl at HA28-30.
3. Loose breakdown W. of HA 51-53 & N. of HA54.
4. The area at HA34 called the "Nervous Breakdown" has a large, loose slab of rock which is especially dangerous.

AREA IV.

1. Several areas of V. loose breakdown (Unmapped)
2. Some exposure 30'-40' in breakdown and fissures.

ALTERNATE RESCUE ROUTES

1. King Solomon's Mind to Big Horn
2. High Leads
   a. "J" Survey
   b. Drill Hole
   c. Dead Rabbit
3. Bypass of Crack through Breakdown

Cave Hazards - Horsethief Cave

All caves contain hazards of some variety. Following is a list of specific hazards that you may encounter in Horsethief Cave.

A. Radiation

1. Air Exposure: All portions of Horsethief Cave have radiation. Levels of radiation vary with location in the cave. The radiation you will be exposed to is known as "radon daughters", which is alpha radiation resulting from the decay of radon gas. Radon gas is a decay product of uranium. The radon daughters have been shown to be a cause of increases in lung cancer. Radon daughter exposure results from breathing the cave air, as particles will not penetrate surface skin cells or clothing. When you inhale, you draw radiation into your lungs. Some radiation particles are exhaled, but some remain in the lungs. The accumulation of particles in this manner may eventually result in health problems. Smoking will increase the effect of radiation on your body.

2. Dust Exposure: Some radiation particles adhere to dust particles (as well as other types of particles in the air). Breathing of dust particles will result in radiation exposure.

3. Water Exposure: If water is encountered in Horsethief Cave, it will be radioactive to a certain extent. Consumption of the water or contact with it may result in radiation exposure.

4. Radiation Exposure Limits: Limits of maximum exposure to radiation have been established by Federal agencies. The purpose of maintaining a record of your travels in Horsethief Cave is to allow BLM to determine the amount of exposure you have had after each trip. When you reach a maximum exposure level, you will be denied access to the cave for a specified period. Exposure is recorded on a calendar year basis. Most spelunkers do not reach the cutoff level in a calendar year.

   You should be aware that other caves may have radiation even if uranium is not known in the area. BLM has no way of knowing about or recording radiation exposure you have experienced in other caves. Since the additional exposure in other caves may push you above accepted limits, you may wish to personally limit yourself as to the amount of spelunking you do in radiation-filled environments.

B. Loose Breakdown (refer to map for zone description)

1. Unstable ceiling

   Zone 1 - vicinity of trail in entrance room

Zone II - top of Big Fissure and overhanging some small leads
- ceiling of Little Red Buddha Room
- exposure to rock fall if chimneying to top of Big Fissure

Zone III - ceiling holes adjacent to Gypsum Wall on west side

Zone IV - CLOSED TO TRAVEL

Zone V - exposure to rockfall in chimney through breakdown in vicinity of Dog Leg
- exposure to loose rock when chimneying beyond end of F Survey
- ceiling at White Buddha at E20

Zone VII - exposure to rockfall while crossing some breakdown blocks in vicinity of L6

Zone VIII - exposure to rockfall in chimneys and on breakdown in area southeast of H14-H16

Zone IX - dangerous loose slab of rock called the Nervous Breakdown at LA34 may block exit if pulled down

2. Unstable floors

Zone II - loose breakdown in Little Red Buddha Room

Zone III - loose breakdown in vicinity of Gypsum Wall

Zone IV - CLOSED TO TRAVEL

Zone V - loose breakdown near Dog Leg
- slippery, old flowstone should be avoided at F29 and F30
- slick, mud-covered breakdown at F22-F23
- large amounts of loose, large breakdown in Montana Room and fissure
- loose breakdown all over Montana Maze
- loose breakdown in E Survey and especially at E1-E5

Zone VII - loose breakdown between D64 and K15
- extremely loose breakdown west of K17; very large, loose breakdown blocks south of K31
- very large, loose breakdown block near K32
- very unstable breakdown floor in Pratt Fall Hall

Zone VIII - very large, loose breakdown on floor southeast of H14-H16

Zone IX - dangerous loose breakdown southeast of H33
- large, loose breakdown east of H36 and south of H34
- loose breakdown crawl at H28-H30
- loose breakdown west of HA51-HA53 and north of HA54

3. Unstable walls

Zone III - 20 foot free climb over gypsum crust at Gypsum Wall
Zone IV - CLOSED TO TRAVEL
Zone VIII - very large, loose breakdown on sides of passage southeast of H14-H16

C. Maze Passages

Zone I - simple maze from A10 to A21
Zone IV - CLOSED TO TRAVEL
Zone V - mazes along north wall near F28-F18 and F1, and along south wall in area of F6
- Montana Maze - disorientation probable
Zone VI - White Dirt Maze - low passageway over long distance
Zone VII - maze with fissures, crawls and phreatic spongework between K25 and L6
- phreatic mazes in areas L1, L11 and L23 - possible hazard to inexperienced cavers.

D. Dust

Dust may cause difficulties in breathing. In some caves it is known to contain disease-causing agents. No work has been done in Horsethief Cave to prove or disprove the presence of such agents. Dust particles will be radioactive.

Zone II - thick dust throughout Denise's Crawl

E. Psychological Problems

Temporary psychological problems may result from claustrophobia and from the intense silence and darkness in the cave.

Zone II - tight constrictions in Denise's Crawl
Zone VI - tight squeeze in chimney at Crack Where the Water Comes Down

F. Hypothermia

Hypothermia may result from any or all of the following: hunger, steady cold temperatures (50° or less), overexertion, damp clothing, lack of proper clothing, lack of precautions.

G. Access - Surface Hazards

The access to Horsethief Cave involves travel via John Blue Canyon. The condition of the road and lack of guardrails, etc. may be a hazard to careless drivers. Winter storms and snow accumulation

may strand individuals at the cave or may make travel over roads to the cave dangerous or impossible.

The hazards and locations of hazards outlined above are not intended to comprise an all-inclusive list of hazards that may be encountered in Horsethief Cave. Cave travel should be undertaken with care and with the realization that hazards of many descriptions may be encountered at any time or location or in any situation.

APPENDIX B

Detailed discussion of histoplasmosis from the Spirit Mountain Caverns report.

Histoplasmosis and other lung diseases: Histoplasmosis is a lung disease associated with inhaling spores of the fungus Histoplasma capsulatum. Although infection is common (Criagle, 1976), there is generally either no detectable illness or only mild respiratory symptoms. However, there is a progressive type of the disease which is often fatal; this most commonly involves an intense exposure to the spores of Histoplasma capsulatum.

Histoplasmosis is endemic in certain areas of the United States, and in some tropical regions as well. Positive histoplasmin skin tests indicate that 80% of the population in the Mississippi-Missouri-Ohio River Valleys have been affected (Craigle, 1976). In contrast, Histoplasma capsulatum has to date been reported at only one site in Wyoming. The site is Spirit Mountain Caverns.

The Center for Disease Control in Atlanta, Georgia made the determination that Histoplasma capsulatum was present in a sample sent to them. The nature of the sample, as described by Lydy (1979) in a letter to the Cody BLM office, was "composed of dirt, feathers, rat pellets, and a variety of unidentified material; really nasty looking stuff". The sample was collected by two BLM cave rangers. Although no information on the precise location from which the sample was collected was found in the BLM files, the presence of feathers in the sample indicates that it was collected either in the Pigeon Roost area or on the route to that area. This was confirmed by Pete Uhl, one of the BLM cave rangers who collected the sample.

Spores of Histoplasma capsulatum have been found only in association with bird droppings and bat guano. Based upon a discussion in 1979 with Dr. Robert W. Lichtwardt, a mycologist at the University of Kansas involved in study of this fungus, spores of Histoplasma capsulatum have never been found associated with droppings from packrats. The explanation for this may be related to differences in the digestive systems and digestive enzymes between bats and birds and other vertebrate animals.

Regardless of the explanation, the restriction of spores of Histoplasma capsulatum to bird droppings and bat guano has cave management significance in Wyoming. Our concern about histoplasmosis can be restricted to areas of caves which contain bat guano or bird droppings.

We saw no bats in Spirit Mountain Caverns; cave dwelling bats are generally rare in Wyoming caves. Packrat droppings are scattered throughout the cave. Large bird populations are uncommonly associated with caves, but Spirit Mountain Caverns, with its large pigeon population, is a notable exception. Pigeon use of the cave is restricted to the Pigeon Roost area, although some of the pigeon droppings and feathers have migrated into some of the small passages on the route between the main level of the cave and the Pigeon Roost area. Packrats have probably helped spread this material around.

During our field work we collected nine samples of soil and fecal material from Spirit Mountain Caverns for subsequent analysis for the presence of spores of Histoplasma capsulatum. The samples were collected in sterile bags using sterile spoons. The samples were given to Mr. Wayne Holm at the BLM office in Cody; he will ship them to the Center for Disease Control in Atlanta, Georgia where analysis work will be done.

Table 1 summarizes data on the location of the nine soil and fecal sample collection sites in Spirit Mountain Caverns; the locations are shown on the map in Figure 17. Table 1 also indicates whether the collection site was a location where cavers were likely to travel and thus be exposed. Some of the samples were collected from packrat debris in small alcoves where people would not travel.

The analysis of samples for Histoplasma capsulatum (as conducted by the Center for Disease Control) takes several weeks. As a result, we have not yet received the results. Once the results are received, we will analyze them in an addendum for any impacts they may have on cave management. BLM personnel will add this addendum (Addendum 1) to all of their copies of the report. However, based upon our present knowledge of the natural history of this fungus and the nature of the cave, we believe we can develop prudent management recommendations for relating to this hazard without waiting for the final results from CDC. Any changes in our conclusions and recommendations will be incorporated in Addendum 1.

Although histoplasmosis is a newly discovered issue affecting cave management in Wyoming, it is not a new issue in other parts of the United States. Management approaches used by other state and federal agencies in areas where histoplasmosis commonly occurs can give some guidance to BLM in dealing with the issue in Wyoming.

The BLM files in Cody contain some very helpful correspondence between Thomas Enright and Warren C. Lewis, M.D. on the subject of histoplasmosis (Appendix B)*. Dr. Lewis states that Histoplasma capsulatum spores have been found in several caves open to the public, including Carlsbad Caverns in New Mexico (administered by the National Park Service). Spores of Histoplasma capsulatum could probably be isolated from Mammoth Cave, Kentucky (administered by the National Park Service), Blanchard Springs Caverns in Arkansas (administered by the U.S. Forest Service), as well as many other public and private caves. At these caves, visitors are not warned of any special hazards. Employees or visitors working or exploring where they could stir up spores are typically cautioned about the disease. We believe this to be a proper course of action.

As mentioned earlier, the severity of the disease tends to be associated with the intensity of the exposure. Fatal cases of histoplasmosis have resulted in Missouri among workmen who were bulldozing out trees and leveling the ground in areas which supported giant starling roosts; nearby residents were not affected. With cavers, cases of histoplasmosis serious enough to involve medical treatment have typically resulted from horseplay in piles of bat guano and/or nearby cave dirt. In addition, a number of cavers who have visited caves in central America or the Caribbean have also suffered bouts with histoplasmosis. Many of these tropical caves contain hundreds of thousands and even millions of bats; cave

* Found only in the Spirit Mountain Report.

Table 1

Location and related data on soil and fecal samples collected in Spirit Mountain Caverns for *Histoplasma capsulatum* analysis.

Sample #	Cave Level	Location	Caver Exposure Likely?
W-1	1	Top of Credibility Gap; packrat debris.	No
W-2	1	Top of Credibility Gap; typical cave dirt	Yes
W-3	between 2 & 3	Guano Room Bypass route; crawl immediately above Guano Room Pit. Typical cave dirt.	Yes
W-4	3	Lower end of main linear passage.	Possibly
W-5	4	Main route in lowest level of the cave; typical cave dirt.	Yes
W-6	2 on route to 1	Halfway between main passage and Pigeon Roost Area. Vicinity of previous positive histo sample. Cave dirt, packrat droppings pigeon feathers and droppings.	Yes
W-7	2	Packrat debris in alcove along the main passage 80 feet from gate.	No
W-8	2	Main passage at the intersection with the route to the Pigeon Roost area. Typical cave dirt.	Yes
W-9		This sample collected at Horsethief Cave	
W-10	between 2 & 3	Guano Room Bypass route; breakdown chamber above Guano Room Pit. Typical cave dirt.	Yes

exploration involves substantial contact with bat guano. Prudent cavers who have a concern for the well-being of their lungs do not romp through the guano nor frolic in dust contaminated with bat or bird feces.

Based upon our understanding of histoplasmosis, the risk of potentially contacting a detectable case of this disease is negligable in most portions of Spirit Mountain Caverns. The hazard exists only where there is a substrate of pigeon droppings; these conditions are found only in the Pigeon Roost area and in immediately adjacent areas.

People traveling toward the Pigeon Roost area from level 2 of the cave must pass through some steeply inclined crawlways where it is impossible not to stir up dust. As one nears the Pigeon Roost area, this dust becomes obviously contaminated with pigeon droppings and feathers. In order to make it all the way to the Pigeon Roost area, it is now necessary to partially excavate a connecting crawlway; the crawl is primarily plugged with pigeon droppings. The fact that we did not excavate this passage and continue on to the Pigeon Roost area is indicative of the seriousness with which we view this hazard. Similarly, we did not descend into the Pigeon Roost area from outside the cave; we did not view this as prudent either.

Histoplasmosis is not the only disease which can be associated with bird droppings. Several years ago one of the authors of this report had a serious case of parrot fever and pneumonia which lasted for several weeks. This was a result of cleaning out a Missouri turkey house which had been unused for several years. Possibly this or similar diseases could result from travel into those portions of Spirit Mountain Caverns which are heavily used by the pigeons.

Management recommendations on histoplasmosis: With respect to the hazards of histoplasmosis and other bird-related diseases, the following cave management actions are recommended.

1. The risk to visitors does not warrant the closure of the cave or general restriction of access. Many people have visited the cave in the last few years, yet to our knowledge there have been no reports of cases of histoplasmosis which might have been related to visitation of this cave.

2. All visitors to the cave should be cautioned that the fungus Histoplasma capsulatum has been isolated from a sample containing pigeon feathers and feces, packrat droppings, and cave dust. Although the pigeon feces are almost certainly the only medium which will support the spores of this fungus, it is prudent not to stir up any dirt or fecal material found in the cave. An adequate gate and a permit system for the cave would insure that all visitors were cautioned about this hazard.

3. Visitors should be warned that the Pigeon Roost area and the route to this area are considered to be hazardous because of the fungus Histoplasma capsulatum and the abundance of pigeon feces, which provide a good substrate for this fungus.

4. A sign should be placed on the route to the Pigeon Roost area informing visitors that this is the area of the cave where the hazard of histoplasmosis is believed to be significant. The sign should be placed at the entrance to the first crawlway after leaving the main cave passage on the route to the Pigeon Roost area. The sign should strongly recommend that people not proceed further. The sign might also state that the passages beyond are small and not of particular interest.

5. Spores of the fungus Histoplasma capsulatum can persist in soils for many years. Exclusion of pigeons from the cave would not solve the problem. Soil sterilants do not effectively kill spores of Histoplasma capsulatum. Histoplasmosis is a long term and uncorrectable situation which will always require at least some management attention.

APPENDIX C

Discussion of Cave Radiation

All caves contain some natural alpha radiation. The caves administered by the Bureau of Land Management are no exception. The purpose of this discussion is to give land managers an understanding of the issue, an assessment of the significance of the possible health hazard, and our recommendations for dealing with the issue.

General cave radiation information is included in this appendix so that it will not need to be repeated in three separate reports. Data on cave radiation which is specific to a particular cave is found in the text discussions about that cave; the reader should consult this material.

The cave radiation issue: Most people do not realize that there are varying levels of natural alpha radiation everywhere. Detectable concentrations can be measured out in the open air, in buildings, and in all caves. Natural alpha radiation occurs because there are small amounts of uranium and thorium in all rocks and soils. During the atomic decomposition of these materials, alpha radiation is produced.

Since alpha radiation is derived from materials in soil and rock, buildings made of earth and rock materials tend to have higher alpha radiation concentrations than buildings made of materials such as wood. Because they have less air exchange and more contact with soil and rock, basements and energy-efficient underground buildings typically have higher alpha radiation concentrations than above-ground buildings.

Alpha radiation can also be measured in caves, since caves are surrounded by rock and soil. Since natural radioactive materials are not distributed uniformly in soils and rock, and since air circulation patterns are not uniform in caves, alpha radiation concentrations may vary from point to point in cave systems.

Very high alpha radiation concentrations can be found in portions of uranium mines which are poorly ventilated. Medical studies of miners have indicated that exposure to alpha radiation increases the liklihood of eventually developing lung cancer. The greater the contact with alpha radiation, the greater is the possibility of eventually (perhaps in 20 or 30 years or so) developing lung cancer.

An obvious question is, why should alpha radiation increase the liklihood of lung cancer? Alpha radiation is a low energy ionizing radiation which can damage extremely delicate cells. Lung cells are extremely delicate, and they do appear to be damaged by alpha radiation. Although we do not know what causes lung cancer, it does appear that damage to lung cells (whether from alpha radiation, cigarette smoke, air pollution, or a host of other things) increases the liklihood of lung cancer.

There has been no research done to determine safe limits for exposure to natural alpha radiation. As we consider alpha radiation, it is important that we recognize it as a form of radiation which we cannot totally escape.

It is estimated that about 80% of lung cancers in the U.S. are related to cigarette smoking. Other lung cancers are related to asbestos and other carcinogens. Natural alpha radiation is well down the list of hazard factors.

Studies were conducted by the National Institute for Occupational Safety and Health on employees at National Park Service caves open to the public (these include Mammoth Cave, Carlsbad Caverns, and about half a dozen others). These studies did not show any correlation between employment in caves and increased occurrences of lung cancer. Since in medical research it is almost impossible to show that something is safe, these tests did not show that periods of cave work might not increase the liklihood of lung cancer by some small amount.

Aside from the research mentioned above, most of our insight into possible alpha radiation health problems comes from medical studies of miners. There are several reasons why alpha radiation as encountered in caves may be less hazardous than that encountered in mines. For example, mine air is contaminated by diesel smoke and dust, both of which are harmful to the lungs. In contrast, cave air is typically cleaner.

Significance of the human health risk: Although alpha radiation as encountered in caves may not be as harmful as alpha radiation as encountered in mines, it seems prudent to presume that it is. Based upon this presumption, we can use some of the rule of thumb values relating alpha radiation exposure in mines to the increased liklihood of lung cancer, and develop some numbers which will help place the cave radiation issue in perspective.

Let us assume that a "typical caver" takes five caving trips to BLM administered caves in a year. Let us further assume that two trips are to Horsethief Cave (where he spends a total of 20 hours), one trip is to Spirit Mountain Caverns (where he spends a total of 5 hours), and the last two trips are to La Caverna de Tres Charros (where he spends a total of 10 hours). This represents a total of 35 hours underground. Based upon mean alpha radiation concentrations measured at these caves, he would receive a total of 0.153 working level months of natural alpha radiation; his mean exposure rate would be 0.75 working levels per hour.

During the year that our "typical caver" does the caving outlined above, he will receive about 15% of his total alpha radiation exposure from BLM caves. The remaining 85% of his exposure comes from other environmental exposure; most of it is from living and working in buildings.

At age 30, our "typical caver" would have received only about one half of one percent of his total alpha radiation from his year of exploring BLM administered caves. The majority of his exposure would have been from buildings.

If we had 100 active cavers each year, and each of them followed the schedule of our "typical caver" and experienced similar radiation exposure from BLM caves, we should anticipate one excess lung cancer among this group every 875 years. Of course, this cancer might be curable. Based upon our "typical caver", we should anticipate one excess lung cancer for every 2.3 million man hours of caving in the three caves involved in our study.

If our "typical caver" lives in Laramie, his five cave trips in a year will represent about 3,500 miles of highway travel. Based upon national highway fatality statistics, there are approximately 3.4 fatalities in the United States for every 100 million miles driven. As low as this value is, the chance that the caver will be killed in a traffic accident on a cave trip is about 8 times greater than the probability that he will ultimately suffer a lung cancer from his year of caving in BLM caves. On a per hour basis, the chance of our "typical caver"

ultimately getting a lung cancer from exposure to cave air in BLM caves is about equal to the risk of being killed in the crash of a commercial Boeing 737 on a domestic flight. The Boeing 737 is the safest U.S. commercial airliner; this plane has experienced only 0.04 fatalities for every 100,000 hours of passenger flight time.

Among federal land management agencies, the National Park Service has been a leader in warning the public about hazards. The NPS (with the concurrence of the Environmental Protection Agency) does not view the cave radiation hazard as sufficient to justify warning of visitors at any NPS cave open to the public. During the course of a year, visitors to either Carlsbad or Mammoth receive a total alpha radiation exposure 400 times greater than that received from BLM caves by 100 active cavers following the schedule of our "typical caver". Medical research indicates that it is the total dose and not the rate of exposure which is important; for this reason the comparison of exposures between NPS and BLM caves is appropriate. Private show-caves and the National Park Service do inform employees about cave radiation; this is required under the precautionary cave radiation standards presently in force.

In an era where the word "cancer" carries panic connotations it is easy to react too strongly to a "newly discovered" potential hazard. It is our view that this is precisely what has happened with the cave radiation issue. As a result of overly reactive fears that caused a "caving causes cancer" campaign, cave management and cave safety efforts have been diverted away from things which are crucial, and have been concentrated on a risk which is minor in significance.

In Horsethief Cave, the cave radiation hazard can be compared quantitatively with the hazard of becoming so seriously lost that rescue is necessary. This comparison will further help to put the cave radiation hazard in perspective as a minor (and not a major) hazard.

The extensive portions of Horsethief Cave were discovered in 1970 (Sutherland, 1971). Within less than a year, one person was lost in the cave for 36 hours, and had to be rescued by cavers (Sutherland, 1971). In the BLM files in Cody we noted that a party of two people also became lost and required rescue a few years ago. Becoming lost and/or losing one's lights is a major hazard in Horsethief Cave.

Based upon data in the Cave Management Plan (BLM, 1978) visitation in Horsethief Cave is now limited to 400 people per year; this limit was based upon past usage. If we assume that the average trip in this cave lasts 10 hours, and that there have been 400 people per year visit this cave in the nine years since its discovery, then this represents a total of about 36,000 hours of cave use. Since at least three people have become lost and required rescue during this time, one person becomes lost for about every 12,000 hours of caving time. If we compare this value to the radiation hazard experienced by the "typical caver" spending 35 hours a year in three BLM administered caves, we derive a very interesting value. The risk of becoming lost in Horsethief Cave and requiring rescue is about 200 times greater than the risk that someone will ultimately experience lung cancer as a result of exposure to alpha radiation in BLM caves. To date, there have been no significant injuries or fatalities among those lost in Horsethief Cave; the people have been lucky. It certainly does not indicate that being lost is a harmless event.

Concern about cave radiation has diverted management attention away from more significant safety issues. This is clearly illustrated

by the above example. There are many other cave safety and cave management issues which are far more important and crucial than the cave radiation issue.

Finally, warnings to visitors should reflect a priority ranking which is related to risk. To do otherwise may result in visitors concentrating on trivial risks while paying less attention to major hazards. Furthermore, failure to adequately assess the magnitude of risks damages the credibility of the person and the agency giving the warnings; this can result in the visitor largely ignoring all warnings.

Management recommendations for dealing with the cave radiation issue: This appendix includes, as Attachment 1, the precautionary cave radiation health standards adopted by the National Caves Association. These are the standards which are currently in force for show-caves (commercial caves). There are no state or federal standards which apply to human exposure to alpha radiation encountered in caves. It is the policy of the federal Occupational Health and Safety Administration (OSHA) that federal operations shall be governed by health and safety standards no less stringent than those in force in the private sector. For this reason, the precautionary cave radiation standards which are enclosed are national standards and apply to federal agencies.

The precautionary cave radiation health standards (Attachment 1) are designed for show-caves which are open to the public. They are not specifically designed to cover undeveloped or "wild" caves such as those administered by BLM in Wyoming. However, the precautionary standards for show caves do provide extremely helpful guidance for managers of undeveloped caves. Our recommendations for dealing with the cave radiation issue rely heavily on the existing precautionary cave radiation health standards, and are compatable with them.

Our specific management recommendations are as follows:

1. Alpha radiation should not be considered as a major health and safety issue in cave management.
2. Based upon alpha radiation concentrations measured in Spirit Mountain Caverns and the fact that most visitation will be of short duration, we do not believe it is necessary for BLM to caution visitors to this cave about cave radiation. We estimate that the average visitor will spend about two hours in this cave. Based upon our measurements, the total amount of alpha radiation he will receive from this cave is approximately equal to that he would receive from spending four days in a building.
3. Based upon the low alpha radiation concentrations measured in La Caverna de Tres Charros, we do not believe it is necessary for BLM to caution visitors to this cave about cave radiation.
4. In view of the existing precautionary cave radiation standards and decisions by other federal agencies that visitors need not be warned about cave radiation at caves like Mammoth and Carlsbad, we do not believe it is necessary for BLM to caution visitors to Horsethief Cave about cave radiation.
5. Because visitors often spend long periods of time in Horsethief Cave, BLM might wish to bring the cave radiation issue to the attention of visitors to this cave. A possible wording for handout material for Horsethief Cave is in the health and safety considerations section of the Horsethief Cave report.

6. With respect to employees doing cave work, BLM should comply with the provisions of the precautionary cave radiation standards (Appendix 3, Attachment 1).

NATIONAL CAVES ASSOCIATION

Precautionary Cave Radiation Health Standards for Natural Caves Developed for Visitation by the General Public. Adopted April, 1978; Ratified November, 1978.

1. Where radiation monitoring is not done, underground work shall not exceed 700 hours per year for any employee.

2. Where radiation monitoring is done, annual cumulative radiation exposure shall not exceed 4.0 working level months of alpha radiation exposure for any employee.

A. Where monitoring is done, and adequate data have shown a seasonal repeatability in radiation concentration levels, professional scientific judgement shall be exercised as to the frequency of subsequent monitoring.

B. For monitored caves where the data base does not show a reasonable predictability in radiation concentration levels for the period being sampled, the following monitoring frequency will be used for monitoring occupied areas during those times when they are being regularly visited by employees:

0 to 0.10 working levels: Annual measurement during that season when underground work time is greatest.
0.11 to 0.20 working levels: Semi-annual sampling.
0.21 to 0.30 working levels: Quarterly sampling
Over 0.30 working levels: Weekly sampling and record keeping on employee exposure accumulations.

Note: The working level range is based upon the average of the values obtained in a single sample set. The maximum average value on record should be used unless collected data suggest that this set is atypical. This table should be used flexibly by cave managers as a "sliding" scale linked with seasonal cave radiation variations.

3. Smoking in caves, either by employees or visitors, is prohibited.

4. Except as provided below, cave air shall not be used to ventilate buildings used by employees or visitors, nor shall cave air be allowed to freely enter such buildings:

Exception 1: Buildings which are used exclusively for entry to or exit from a cave are excepted.
Exception 2: Buildings where no individual employee spends an average of more than 5 hours per week are excepted.
Exception 3: Buildings where radiation monitoring indicates that average alpha radiation levels are less than 0.10 working level are excepted. This applies regardless of whether radiation control measures are utilized in the building or not.
Exception 4: Buildings where radiation monitoring indicates that average alpha radiation levels are less than 0.30 working level are excepted if cave air was used for ventilation of this building during the summer of 1977.

5. The potential health hazard of alpha radiation in caves must be explained to all permanent employees who will be doing any underground work before they begin their employment.